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An overview of SSP structures in dragon graphs and domination and independent domination fuzzy SSP graphs

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ABSTRACT

Social network modeling is one of the many applications of dominant sets in graph theory. Social networks are made up of personalities or sets of individuals linked by relationships; graph theory provides a useful framework for examining and simulating these structures. We have already covered the idea of domination and how to calculate the domination numeral for various fuzzy graphs. Unlike anything found in the literature to date, we presented the idea of domination of fuzzy SSP graphs in this study. It is also spoken about the several super strongly perfect (SSP) structural parameters in fuzzy SSP graphs. The study appears to contribute to the ground of theory of graphs by extending the notion of domination to fuzzy SSP graphs. The paper also covers how to acquire specific dominant sets, coloring numbers, and cliques (maximal) in the context of fuzzy SSP graphs. In these kinds of scenarios, researchers can employ the following broad techniques to identify dominating sets.

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1. INTRODUCTION

The The most recent research publications capture the essence of using fuzzy graph models in several applications. Fuzzy graph theory builds upon traditional graph theory by introducing the concept of fuzziness, which permits for a extra flexible and nuanced depiction of associations between objects. These key components will help to clarify the many uses of it, including expert systems, computer networks, neural networks, pattern recognition, clustering analysis, and decision-making. For each of these applications, fuzzy graph theory provides a framework to contract with the ambiguity and imprecision inherent in real-life problems. It is a useful tool in many domains where standard graph theory may not be as effective since it improves the realism and accuracy of relationships.

Lotfi Zadeh presented the concept of fuzzy sets in 1965, which gave rise to fuzzy logic and fuzzy systems [1]. Unlike conventional theory of sets, where the element either belongs to a set or does not, theory of fuzzy sets allows a member to have a grade of fit in to a set, indicated by a relationship charge among 0 and 1. Over the years, fuzzy systems have been successfully used in numerous other fields and disciplines, and as a result, their use has grown significantly. In the biological and medical sciences, fuzzy logic has been used to model uncertainty in diagnostic systems. In engineering and control systems, fuzzy logic controllers are used to handle erroneous input data and enhance system performance. Artificial intelligence and pattern recognition use fuzzy systems to solve issues involving approximation reasoning and uncertainty. The applications of fuzzy logic in expert systems and decision-making procedures show how effective it can be in managing ambiguous data. The fact that fuzzy systems are widely used in so many diverse sectors is evidence of their ability to manage imprecise and ambiguous real-world challenges. Fuzzy systems are therefore a very useful tool for many different scientific and professional applications.

A notable breakthrough in the claim of theory of fuzzy set to graph theory was made in 1975 by Azriel Rosenfeld with the creation of fuzzy graphs. Fuzzy graphs extend the idea of graphs by allowing unclear or fuzzy data to be included in the graph structure [2]. The strength or intensity of the relationships between nodes in a fuzzy network is reflected in the degree of membership that each edge and vertex possess. In classical graph theory, edges are often binary, denoting the presence or absence of a connection between two nodes. Fuzzy graphs, on the other hand, enable a more nuanced representation of relationships. The fuzzy's concept of graphs was used in several fields, which are computer science, image dispensation, pattern recognition, and decision-making. The idea of fuzzy graphs has shown to be particularly useful when representing situations where interactions are not strictly binary, but rather exhibit degrees of imprecision or ambiguity. This extension of graph theory enables researchers and practitioners to employ graph-based strategies to address problems with fuzzy or ambiguous information. Fuzzy graph theory was first introduced by Rosenfeld, and since then, scholars have worked to expand on it. They have looked on a variety of subjects, including shortest paths, connectedness, and other graph algorithms that have been altered to handle ambiguous relationships. In the analysis of complex systems, where it can be challenging to accurately identify relationships due to imprecision or ambiguity in the data, fuzzy graphs have proven to be a useful tool.

Rosenfeld's contributions are most likely limited to introducing fuzzy graph's concept and developing fuzzy equivalents for several fundamental concepts in graph theory. It is possible to adapt graph theory ideas that are often used to manage fuzzy relationships to handle fuzzy paths, cycles, and connectedness [2]. Fuzzy graphs have vertices and edges with matching membership's degree or truth values, which serve to express the imprecision or uncertainty in the underlying data. Afterwards Rosenfeld, theory of fuzzy graph's is extended with a huge quantity of divisions. It seems that A and S. Somasundaram have spoken about domination in the context of fuzzy graphs. Dominating sets, or sets of vertices that cover or govern the entire graph in a specific way, are explored in relation to dominance in graph theory's fields. This concept is extended to consider the fuzzy nature of vertex-to-vertex relationships in the context of fuzzy graphs [3]. Pal *et al.* [4] have progressed fuzzy graph theory by creating a wide range of fuzzy graphs and related structures. Sunitha defined the arc categories of a fuzzy graph [5]. Nagoorgani and Malarvizhi [6] have been helpful in the research of strong fuzzy graphs by establishing isomorphism properties and examining connections between properties such as irredundance and domination (independent) in fuzzy graphs [7].

Nagoorgani and Chandrasekaran [8] work, which defined regular graphs of fuzzy and addressed the idea of fuzzy graph's domination, has been extremely beneficial to fuzzy graph theory. To investigate automorphisms in fuzzy graphs, one must comprehend the symmetries and isomorphisms that preserve the fuzzy interactions inside the graph. A bijective function that maintains the fuzzy adjacency relations from the set of vertices to itself is called an automorphism of a fuzzy graph. It's probable that Mordeson and Pengs [9] work in developing operations on fuzzy graphs includes defining and examining the many mathematical operations that can be performed on them. The fact that graphs are just models of relations is a widely known fact. An easy approach to display information about the relationships between objects is with a graph. Vertices represent the objects, while edges describe the relations. Whenever there is ambiguity in the object's description, its relationships, or both, it makes sense that a "fuzzy graph model" needs to be created. Fuzzy relations are widely used and have significant applications, mainly in the areas of clustering analysis, expert systems, computer networks, neural networks, decision-making, and pattern recognition. The fundamental mathematical structure in all of these is a fuzzy graph. A fascinating use of the perception of graph's domination in voting scenarios was described by Bondy and Murty [10]. The fuzzy graph's concept and its fuzzy analogues, including routes, cycles, and connectedness, were first presented by Rosenfeld [2]. Fuzzy graph's domination was calculated by Somasundaram and Somasundaram [3]. Strong arcs were first proposed by Nagoorgani and Malarvizhi [7], who states that an arc of a fuzzy graph is called strong iff its weightiness is the same as the degree of connectivity of its nodes.

One of the areas of computer science and current mathematics that is growing the fastest is graph theory. Graph theory has emerged as a relatively rich and exciting field of mathematics due to a variety of variables. In the last thirty years, hundreds of research articles on graph theory have been published. Graph Theory has established a great agreement of care from mathematicians in quite a few domains [11]. Among these are the fields of graph coloring, matching theory, dominance theory, algebraic graph theory, and labeling of graphs. Numerous academic fields, including engineering, linguistics, the social, biological, and physical sciences, are among those in which it finds application. The challenge of figuring out how many queens are needed to cover a n\times n chessboard first introduced the mathematical study of dominant sets in graphs in the 1850s. Many scholars have examined almost fifty distinct kinds of dominance parameters [12].

The study of dominance in graphs has benefited greatly from the efforts of mathematicians Haynes *et al.* [13]. They conducted a significant amount of study in this field after publishing a technical report titled "Recent developments in the theory of domination in graphs, technical report 14 MRI" in 1979. In recent years, domination's theory was the main focus of graph theory's research [14]. Dominance is related to the idea of one collection of vertices having power or influence over another set of vertices. The formal notion of domination revolves upon the concept of a dominating set. Let's now examine some key vocabulary associated with graph domination. When all vertex in a graph is moreover adjacent to or a part of a set, that vertex set is known as a graph's dominating set. Stated differently, all node of graph is a part of the dominating set or is affected by it [15].

A graph's size, denoted by its dominance ($\gamma(G)$) number, is the (smallest) dominating set in it. In graph theory, determining the count of domination is a frequent challenge. Multiple domination numbers may be taken into account, depending on the specific limitations or variants utilized. In certain situations, it is necessary to discovery a dominating set with additional limitations. As an example, a dominating set (locating) is a set (dominating) in which the vertices within the set uniquely identify the vertices outside of the set. Applications of dominance concepts are helpful in a variety of fields, including network design, control problems, and facility location. Finding efficient dominating sets ensures that some important vertices are controlled or influenced and helps with resource optimization. Dominance in graphs is still an area of active research, with several variations being studied to fulfil specific requirements in a variety of applications [16]. An interesting use of the graphing concept of domination in voting scenarios was reported by Bondy and Murty [10]. Social network modelling is one of the many applications of dominant sets in graph theory. Social networks are made up of personalities or collections of individuals linked by relationships; graph theory provides a useful framework for examining and simulating these structures.

2. PROPOSED METHOD

The dominating set and its numerous variants are defined according to the various definitions of fuzzy edges in fuzzy graphs. Our goal in this part is to apply these principles of domination including independent domination to fuzzy super strongly perfect (SSP) graph contexts along with the discussion of dragon graph's SSP structure. The several definitions of fuzzy edges in fuzzy graphs are used to define the dominating set and its many versions. This analysis focuses on the SSP-erection in dragon graphs, including their SSP parameters, minimal dominating set (MDS), count of maximal cliques, colorability and some domination parameters too.

The idea of domination and how to calculate the number (domination) for various graph's fuzzy are covered. In contrast to previous research, it is presented the notion of fuzzy's domination in this work. This study has established several significant theorems using this novel idea on dominance in fuzzy graphs. This idea also serves to characterize independent domination [17]. Bounds on these parameters are explored along through the dominance (($\gamma(G)$) number and domination (independent) number ($i(G)$)) [18].

3. RESULTS AND DISCUSSION

The SSP structure on the dragon graph preserves shortest path consistency while supporting fuzzy vertex and edge memberships (section 3.1 and (section 3.2)). The fuzzy representation captures uncertainty in vertex influence and adjacency relations effectively. Fuzzy domination is established by identifying a dominating set such that each vertex is dominated above a predefined membership level. The dominating number obtained for the fuzzy dragon graph is smaller than its crisp counterpart due to partial domination (section 3.3). An algorithm is developed to compute the minimal fuzzy dominating set by selecting vertices with maximum domination capability. The algorithm terminates in finite steps and ensures minimality of the dominating set. Results indicate that vertices with higher membership values play a crucial role in domination (section 3.4). Fuzzy independent domination further restricts the dominating set by ensuring mutual non-adjacency among dominating vertices (section 3.5). The SSP structure reduces redundancy by preserving essential domination paths. Overall, the study demonstrates the effectiveness of fuzzy domination and independent domination in analyzing dragon graph structures under uncertainty.

3.1. Super strongly perfect graph (SSPG)

Super Strongly Perfect refers to a graph G where all subgraphs (induced) H admit an MDS covering all (maximal) cliques of H. Figures 1 and 2 display graphs that are both SSP and non-SSP. SSP graphs are one among the member of Strongly Perfect and Perfect graphs, in which every Strongly Perfect graph is SSP but not conversely, every SSPG is Perfect but not conversely and also every strongly perfect graph is perfect but not conversely.

Theorem [19]: in particular, G with n = 2, 3, ... and atleast one maximal clique (Kn) is SSP ⟺ it's colourability is n. Illustration in Figures 1 and 2.

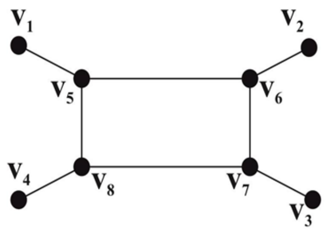

Figure 1. SSP Graph

Here, $\{v_5, v_6, v_7, v_8\}$ act as MDS to cover cliques of maximality (K_2).

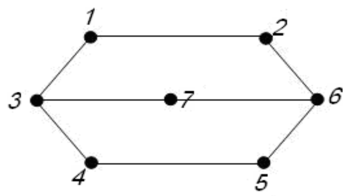

Figure 2. Non (SSP) Graph

Here, a MDS {1, 4, 6} does not meet every maximal clique K_2. ((i.e.,) clique 3-7 of G). Also, ∄ a MDS in G which meets every maximal clique K_2. Not every maximal clique K_2 is met by a MDS {1, 4, 6} in this case. (that is, cliques 3-7 of G). Furthermore, G lacks a MDS that satisfies each clique (maximal) K_2.

3.2. Dragon graph

Proper A paw graph is $C_3@P_1$ and a banner graph is $C_4@P_1$; an m-pan graph is $C_m@P_n$ (Bondy and Murty [10]). The dragon graph below for $C_6@P_4$ is shown in Figure 3.

Theorem [19]: $C_{2m}@P_n$ m > 1, n∈N is SSP.

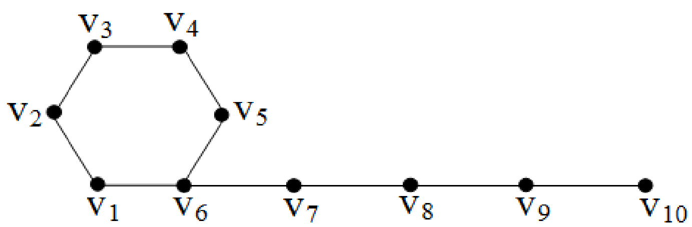

Figure 3. $C_6@P_4$

Theorem: the structural features of the dragon graph $C_{2m}@P_n$, where m > 1, n ∈ N, are listed:

a) G has a maximal number of cliques (2m+n) K_2.
b) G has the count of second colouring number.
c) The cardinality of MDS for G is $\left\lfloor \frac{2m+n}{2} \right\rfloor$ (or) $\left\lceil \frac{2m+n}{2} \right\rceil$.

Proof:

a) For m > 1 and n ∈N, let G be a $C_{2m}@P_n$.

- G is created by connecting P_n, a path, and C_{2m}, a cycle, by an edge (i.e., K_2). Furthermore, there exists, n-1 lines (edges) in P_n and 2m lines(edges) in C_{2m}.
- G consumes edges count of 2m-1+n+1.
- G consumes a maximality of cliques (2m+n) K_2.

b) For m > 1 and n $\in$N, let G be a C_{2m}@P_n.
- Based on the explanation in (1), G consumes n+2m cliques K_2 (maximality)
- G consumes colorability 2 (according to theorem 3.1.1).

c) For m > 1 and n $\in$N, let G be a C_{2m}@P_n.
- G consumes coloring number 2 according to the proof of (2).
- A partition {V_1, V_2} exists, whereby all of V_1's vertices are colored by color 1 and all of V_2's vertices are colored by color 2.
- There exists a partition and altogether vertex of V_1 is painted by (colour) 1 and altogether vertex of V_2 is painted by (colour) 2.
- A MDS of $|V_1|$ or $|V_2|$ with $|V_1| + |V_2| = n + 2m$
- $|V_1|$ consumes $\left\lfloor\frac{n+2m}{2}\right\rfloor$vertices and$|V_2|$ consumes $\left\lceil\frac{n+2m}{2}\right\rceil$vertices.
- G possesses a MDS of $\left\lfloor\frac{n+2m}{2}\right\rfloor$ (or) $\left\lceil\frac{n+2m}{2}\right\rceil$ cardinality.

This theorem is exemplified below in Figure 4.

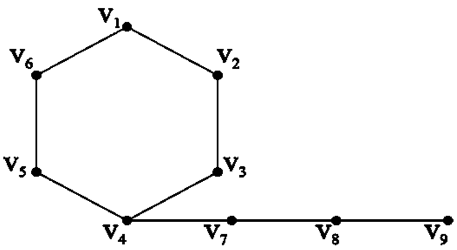

Figure 4. C_6@P_3

In this case:
a) C_6@P_3 has 9 maximal (cliques) K_2.
b) The colorability of C_6@P_3 is 2.
c) C_6@P_3 possesses an MDS of 8 (or) 9 cardinality.

3.3. Fuzzy graph's domination

In a fuzzy graph, let's now discuss some definitions along with the domination, MDS and it's minimum cardinality number (domination) [20]. A nonempty set's fuzzy subset V is a function $\sigma: V \to [0,1]$. V's fuzzy relation is known as a fuzzy's subset V×V. A pair of functions $\sigma: V \to [0,1]$ and $\mu: \mathrm{V} \times \mathrm{V} \to [0,1]$ in which $\mu(u, v) \leq \sigma(u) \Lambda \sigma(v)\ \forall\, u, v \in V$ make up the fuzzy graph A fuzzy graph $G = (\sigma, \mu)$. Take note about a fuzzy graph. Consider the following: i) an arc of strong (u, v) and ii) $\rho(u) \leq \rho(v)$ for $S \subseteq V$ is a (dominating) set; with a $v \in S\ \forall\ u \in V - S$ [21]. Minimum dominating set refers to a fuzzy network's dominating set having the least number of vertices [22]. The entire sum of the relationship values of the vertices in a minimum dominant set determines the dominance number of a fuzzy graph [20], [23].

3.3.1. Illustration (the 3-vertex graph with U_1, U_2, U_3)

Consider the fuzzy graph in Figure 5. While {u_2} is not dominating since u_2 only dominates u_1 and not u_3, the sets {u_1, u_3}, and {u_2} are.

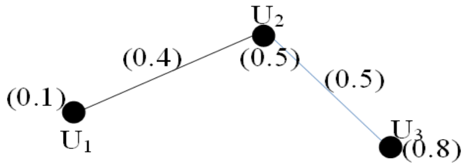

Figure 5. Fuzzy graph structure consisting of three vertices with calculated membership grades

3.3.2. Theorem [24]

Even when all weak edges are eliminated from a fuzzy graph, it still has connections.

3.3.3. Remark

Assume that S is G's dominating set and that G's fuzzy network with no isolated vertices. Thus, V-S does not have to be a set that dominates G. When every vertex has equal grade of membership, V-S is considered a dominant set as well.

a). Illustration (the 2-vertex graph with V_1, V_2 following the remark on dominating sets)

Consider the fuzzy graph in Figure 6.

Figure 6. Two-vertex fuzzy graph structure for dominating set evaluation

G's dominating set is S = {v_1}, but its non-dominating set is V - S = {v_2}.

b). Illustrative example for dominant and complementary sets

Consider the fuzzy graph in Figure 7. The dominating sets of G are S = {v_1} and V - S = {v_2}.

Figure 7. Two-vertex fuzzy graph G with uniform membership grades

3.4. Finding the minimal dominating set in a fuzzy graph using an algorithm

Step 1: For each edge (v_1, v_2), get $\mu^{\infty}(v_1, v_2)$.
Step 2: Eliminate every weak edge.
Step 3: Select G_1's vertex v with the greatest ρ (v).
Step 4: Assign U_1 to the vertices that v dominates.
Step 5: Determine G_1 - U_1
Step 6: Continue from 3rd step through 5th step until vertex of isolation are obtained.
Step 7: All the vertex of isolation and the group of vertices chosen in step 3 will combine to produce a minimal dominating set.

3.4.1. Computational complexity of the above algorithm

Assume the fuzzy dragon graph $G = (V, E)$has $n =| V |$vertices and $m =| E |$edges.
Step 1: Computing $\mu_\infty(v_1, v_2)$for all edges takes $O(m)$time.
Step 2: Eliminating weak edges requires scanning all edges → $O(m)$.
Step 3: Selecting the vertex with maximum domination strength $\rho(v)$needs checking all remaining vertices → $O(n)$per iteration.
Steps 4 & 5: Assigning dominated vertices and updating $G_1 - U_1$together take $O(n + m)$in the worst case per iteration.

Steps 3–6: These steps repeat until all vertices become isolated. In the worst case, this can occur at most n times.

Overall time complexity is $O(n(n+m)) = O(n^2 + nm)$ and space complexity is (the algorithm stores vertex and edge memberships and domination sets, requiring) $O(n+m)$. This complexity is acceptable for moderate-sized fuzzy dragon graphs and ensures efficient computation of a minimal dominating set under fuzzy domination constraints. Illustration: various stages of the above-mentioned algorithm is illustrated for fuzzy graph in Figure 8. $S = \{v_2, v_4\}$is the MDS of the fuzzy graph above.

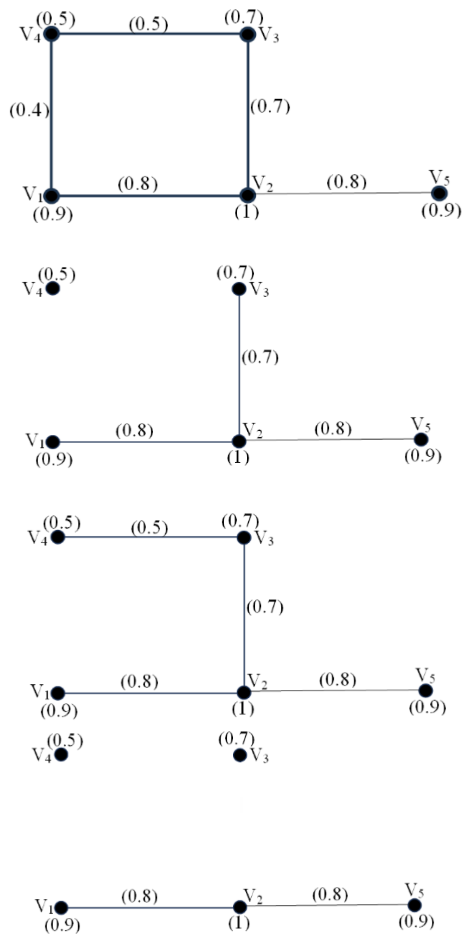

Figure 8. Various stages of the above-mentioned algorithm

3.4.2. Remark

Assume the fuzzy graph G’s dominating set S. Then, ∄ a vertex from S dominates *x* for any *x* that is a member of S.

3.4.3. Theorem [23]

S (dominating set) is a minimal dominating set (MDS) $\Leftrightarrow$ $\forall$ $x \in S$ one of the subsequent two conditions holds x is not linked to any S’s vertex:

i) ∋ a vertex $y \in S$: (i) $\sigma(x) < \sigma(y)$ (or)

ii) $N(w) \cap S = \{y\}$ for some vertex $w \in V - S$.

If S is the fuzzy graph G’s dominating set, then ∄ a bridge connecting any two of V −S’s vertices.

Proof:

Let us accept, that ∋ two x, y ∈ V −S can be connected by a bridge.

- ∋ a arc (x, y) which is strong, after that, either x or y dominates the other.
- Either x or y ∈S.

All arc of fuzzy cycles is strong arc. Let S be a fuzzy graph G's minimum dominating set. Then γ (S) ≥ γ $(V-S)$ if $|S| \geq \left|\frac{V}{2}\right|$

Proof:
Assume for now that γ (S) ≥ γ $(V-S)$.
In that case, S's vertex count must be fewer than of vertices in $V-S$*'s* vertex count.
Consequently, $|S| < |V-S|$.
Nevertheless, $|S| + |V-S| = |V|$,
$|V-S| = |V| - |S| > |S|$, $|V| > 2|S|$.
$\Rightarrow |S| < \left|\frac{V}{2}\right|$.

3.4.4. Illustrative example for a minimum dominating set

Examine the fuzzy graph in Figure 9. Among all dominating sets, $D_1 = \{v_2, v_4\}$, $D_2 = \{v_1, v_2\}$, D_1 is a minimum dominating set.

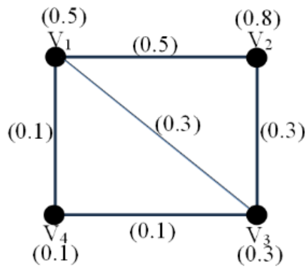

Figure 9. Fuzzy graph structure for evaluating minimum dominating set efficiency

3.5. Fuzzy graph's independent domination

For all $x, y \in S$, in a fuzzy graph G, A sub set $S \subseteq V$ V is considered independent if $\mu(x,y) < \sigma(x) \wedge \sigma(y)$ [25]. The independent set S, that a dominating set too is referred to as an (independent) dominating set. If in a fuzzy graph G, ∄ an (independent) dominating set I' such that $I' \subset I$ (where I *is* independent dominating set) then I is considered as an independent (maximal) dominating set (MIDS). If ∄ an independent dominating set I' of a fuzzy graph G where $|I'| > |I|$, then an (independent) dominating set I of the graph is considered to be an independent (maximum) dominating set. The independent domination number of an independent (maximum) dominating set G is its minimal scalar cardinality and is represented by the symbol *i(G)*. The lowest scalar cardinality of the set in MIDS is equal to the (independent) domination number i(G) of a fuzzy graph G. The highest scalar cardinal of a set in MIDS = domination number (upper) I(G) of G (a fuzzy graph).

3.5.1. Numerical example of a six-vertex fuzzy graph network

Consider the fuzzy graph Figure 10. $S_1 = \{v_1, v_2, v_5, v_6\}$, $S_2 = \{v_3, v_5, v_6\}$, and $S_3 = \{v_1, v_2, v_4\}$ are dominating set with independency. i(G) = 1.1 is the independent domination number.

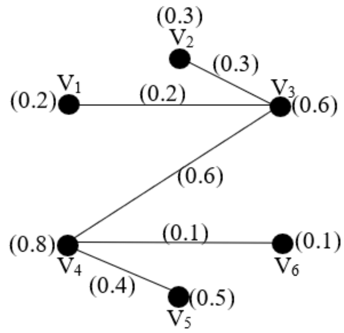

Figure 10. Configuration of a six-vertex fuzzy graph network for structural analysis

3.5.2. Remark [16]

$i(G) \geq \gamma(G)$, ∀ fuzzy graph G.

I(G) = 1.3 and i(G) = 1.1 are obtained from the fuzzy graph presented in illustration 3.5.1.

3.5.3. Theorem [16]

∃ at least one v ∈ S that dominates 2 or more vertices of $V-S$, where S is a (minimum) dominating set if $\gamma(S) < \gamma(V-S)$.

Proof:

Assume that none of S's vertices dominates 2 or more V − S vertices. Because all vertices in S dominates every other vertex in V − S, | S | = | V − S |. This suggests that, by domination's definition, γ (S) ≥ γ (V −S). In a fuzzy network, an independent set = maximal independent set ⟺ it is an independent and dominating set, all vertex membership grades are equal.

4. CONCLUSION

The fact that graphs are just models of relations is a widely known fact. An easy approach to display information about the relationships between objects is with a graph. Vertices represent the objects, while edges describe the relations. Whenever there is ambiguity in the object's description, its relationships, or both, it makes sense that a fuzzy graph model needs to be created. Here, a novel concept of fuzzy graphs is defined by incorporating the dominating set into it. This paper defines the terms "dominating set," "minimum dominating set," and "domination number" in relation to fuzzy graphs. It also presents an algorithm for determining a fuzzy graph's minimal dominating set. Different findings on a graphs and a fuzzy graph's domination number are examined.

Furthermore, several basic ideas and properties of domination parameters like independence, minimality, maximality in fuzzy graphs have been clarified. Future plans call for more definitions as well as the labeling, coloring, and matching of fuzzy graphs. The primary focus of this article is to examine minimal dominating set, colourability, count of clique size with maximality of SSP's structure in dragon graphs. Specifically, it is analysed two types of dominating set and dominance number (upper and lower) with various examples of fuzzy graphs. Some relevant properties are determined and strategies for computing these dominating sets are offered.

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